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Conditioning as Emotional Sensitization and Differentiation[1]

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INTRODUCTION

STUDENTS of the learning process have been much impressed by the probable significance of an emotional factor which might be variously called emotional excitation, anxiety, vigilance, or alertness (8, 11, 13, 18). Work on cardiac reactivity in this laboratory over the past 17 years has indicated that the heart is an excellent organ for the study of emotional excitation.

The purpose of the present research was to study certain cardiovascular aspects of motor learning in a conditioning situation where the motor conditional reflex (cr) could be contrasted with the associated cardiac changes at various stages of the development of both responses.

The operational aim of the research was the study of the latency and the amplitude of the cardiac and motor responses to stimuli signalizing different intensities of electrical stimulation. This is an extension of the work originally done in this laboratory relating the quantity of food reinforcement to the size of conditional and unconditional salivary reflexes (4).

PROCEDURE

Pavlovian methodology was employed. Four dogs, one to two years old, two male and two female, served as subjects. The experimental room consisted of a sound-shielded enclosure (camera) that separated the animal from adventitious stimulation and the operation of the recording apparatus. Leg movements and respiration were recorded by kymograph, and heart rate (HR) by a cardiograph. General behavior was observed through a one-way screen.

The problem presented to the animals required that they discriminate three auditory conditional stimuli (csi), each of the three being repeatedly reinforced (paired) with a specific intensity of electrical stimulation applied to the skin of the left foreleg. An audio-oscillator produced the csi, three notes an octave apart and of slightly less intensity than conversational speech, 256 (csa), 512 (csb), and 1,024 (csc) double vibrations. Table

[1] Papers on this work were read before the American Physiological Society (2) and the American Psychological Association (3). This work was done in the Pavlovian Laboratory at the Johns Hopkins Hospital and was supported in part by funds from the American Heart Association.

[2] Dr. Roscoe A. Dykman was a Public Health Service Research Fellow of the National Institutes of Mental Health at the time of the work (1950-1951).

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1 shows the electrical unconditional stimuli (USi) arranged in their order of intensity as USa, USb, and USc. The only significant changes made in USa and USb in the last 200 trials were for the dog Whittier. The intensity of USc was increased for every animal. All of the USi had to be increased for Whittier because he was responding less frequently each day.[4]

There were three major phases of training: (*a*) The dogs were habituated to the camera and the Pavlov stand (a wooden frame which permits the dog a limited degree of movement). (*b*) The animals were given the three tones without reinforcement. This is designated as orienting or preconditioning control training, the purpose being to establish basal behavior levels (motor stepping and HR), and to eliminate the "innate" responses to the three tones. Such preliminary training served to overcome the novelty or strangeness of the situation to the animals, and thus reduced the diffuse excitatory phase of the investigative action. (*c*) After these preliminary preparations, the tones were given in a regular series of combinations with the electrical stimuli (USi). The order of presentation of these signals was always the same; i.e., csa-USa, csb-USb, and csc-USc. The csi lasted 5 seconds and the USi 0.6 second. The period from cs onset to US was 4.6 seconds; thus the stimuli overlapped for 0.4 second. A mechanical timer gave a cs-US sequence every two minutes, and three csi with their USi constituted for tabulating purposes one trial run.

During the middle of orienting training, different intensities of the USi were given at the end of two daily sessions to approximate the values that should be used for conditioning. The main reason for giving shocks during orienting training was to be able to initiate conditioning trials without first approximating the USi intensities. USa was adjusted to an intensity which would just give a consistent leg-withdrawal, USc was just below that intensity which would cause an animal to whine, and USb was intermediary between USa and USc in intensity. In the last 200 conditioning trials USc was adjusted to an intensity which would consistently cause an animal to whine and withdraw its whole body as well as the US-leg away from the stimulus. Slight adjustments were made in the USi during the first 30 to 50 conditioning trials, and a similar variable adjustment period followed the changes in the USi after 200 conditioning trials. For all practical purposes these adjustments were negligible and may have been unnecessary.

Following Trial 200 the criterion of conditioning was placed at 75 per cent

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[4] A paper this long containing technical terms that are used many times requires certain abbreviations. The following have been adopted from those used in the past work of this laboratory (6).

Stimulus designations:

- cs—conditional stimulus, csi the plural form.
  - csa—tone of 256 double vibrations presented for 5.0 secs.
  - csb—tone of 512 double vibrations presented for 5.0 secs.
  - csc—tone of 1,024 double vibrations presented for 5.0 secs.
- US—unconditional stimulus, USi the plural form.
  - USa—a low intensity electrical stimulus presented for 0.6 sec.
  - USb—a medium intensity electrical stimulus presented for 0.6 sec.
  - USc—a high intensity electrical stimulus presented for 0.6 sec.

Response designations:

- cr—conditional reflect, crs the plural form.
  - cra—conditional reflex resulting from the reinforcement of csa by USa.
  - crb—conditional reflex resulting from the reinforcement of csb by USb.
  - crc—conditional reflex resulting from the reinforcement of csc by USc.
- UR—unconditional reflex, URs the plural form.
  - URa—unconditional reflex produced by USa.
  - URb—unconditional reflex produced by USb.
  - URc—unconditional reflex produced by USc.
- HR—heart rate, HRs the plural form.

In these experiments the UR is the physiological reflex leg withdrawal produced by painful electrical stimulation. The cr is the acquired "duplication" of the UR elicited by the three auditory signals.

TABLE 1

MILLIAMPERAGE FOR THE ELECTRICAL USi

Dog	First 200 Trials			Last 200 Trials		
	USa	USb	USc	USa	USb	USc
Isis	2.0	2.5	3.1	2.0	2.5	3.6
Blanket	1.8	2.4	3.1	1.8	2.4	3.6
Whittier	1.8	2.4	3.2	3.1	3.7	4.9
Schnapps	1.6	2.0	2.6	1.4	2.0	3.2
Average	1.8	2.3	3.0	2.1	2.7	3.8

differentiation. To qualify as successful each animal had to give 18 appropriate reactions to the three different tones in a conditioning session consisting of 24 presentations of the tones; i.e., 18 cardiac excitations or motor crs differing in magnitude so that cra < crb, crb < crc, and crc > cra.

Each dog was given 10 trials (30 sequences of tones and their electrical stimuli) per day for the first 190 trials. After this, all conditioning sessions consisted of seven to 10 trials depending on the restlessness of the animal. In the preliminary orienting training, 10 to 15 repetitions of the three tones were given in each session. Kymograph and cardiac records were taken every 50 to 60 trials during conditioning and somewhat less often during the orienting training.

The daily procedure for conditioning was as follows: *(a)* The dog was brought into the experimental room and allowed to play and run free for a few minutes, then offered all the biscuits he would eat. *(b)* He was placed in the Pavlov stand, and the collar was fastened to an overhanging hook. *(c)* Two US electrodes were applied with electrode paste about one inch apart on the shaved left forepaw. Electrical resistance was measured between the electrodes and if the resistance registered over 1,400 ohms, the electrodes were removed. The paste was then reapplied and thoroughly rubbed in, and this usually lowered the resistance. The average daily resistance for all dogs was 950 ohms with a standard deviation of ±250 ohms. The milliamperages (ma.) of the USi were made about equal from day to day by adjusting resistors of three independent electrical generator circuits in relation to the resistance of the animal. The resistors were in series with the animal. *(d)* Conditioning trials were given as described in the above paragraphs. The voltage drop across the series resistors for each US was observed with a cathode ray oscilloscope while the animal was being stimulated. Several readings were taken with the oscilloscope in the early conditioning sessions until a graph for the various relationships could be obtained. Neglecting the impedance effect of tissue, the ma. passing through the animal was calculated by Ohm's law. The resistors in the generator circuits were maintained at high values to diminish the impedance effect. *(e)* The dog was removed from the camera and the left foreleg was washed with warm water to remove the electrode paste. When the electrode paste was not removed the skin resistance increased on subsequent days. The animal was then petted, fed, and allowed to play and run free in the experimental room.

RESULTS

1. *Preconditioning Control Training*

The orienting reflex variously termed investigatory, focusing, questioning, or "what is it" reaction, is the natural response which an animal gives to most novel stimuli (14, 16). It should be distinguished from the startle reflex which is a far more rapid, "tensing" response to traumatic stimuli. In the orienting reflex the dog turns his head slowly toward the source of the novel stimulus (motor reflex), and this movement is associated with certain visceral changes in respiration, HR, and sometimes salivation. The orienting reflex has been extensively studied (16); it is neces-

sary for the purpose of this paper only to state that it was extinguished before the beginning of the conditioning trials.

2. *Comparison of the HR and Motor cr Changes to the Three Auditory Signals with Respect to their Time of Appearance and Differentiation*

A. *The character of the early responses.* In understanding the learning process it is essential to consider very carefully the behavior of animals in *the first few conditioning trials.* The results for the first three conditioning trials are presented below. The average HR and the motor response (leg withdrawal) changes occurring to csi and USi are given on the second and third lines; and the responses occurring in the period before the signals on the italicized line above.

The two figures in the italicized line represent the periods 20-0 and 5-0 seconds before the tone, respectively. The figures immediately following the csi are for the tone period (responses in this period are usually designated as crs), and the two figures following the US are for the periods 0-5 and 0-20 following the onset of the electrical stimulation. The motor response reflects the dual aspects of frequency multiplied by maximum amplitude. For example, if the greatest amplitude of a motor response in a certain unit of time was 2 centimeters on the kymograph record, and if this response occurred three times, it was given a score of 6. HR is entered as beats/minute. All the figures below are the averages for the four dogs.

Trial 1

Control—HR (97, 100); motor response (2.5, 0.51)
(A) csa—HR (102); motor response (0.68)
USa—HR (106, 98); motor response (2.0, 3.1)

Control—HR (93, 104); motor response (2.1, 0.48)
(B) csb—HR (96); motor response (0.58)
USb—HR (101, 95); motor response (4.0, 10.0)

Control—HR (93, 101); motor response (1.5, 1.5,)
(C) csc—HR (98); motor response (0.0)
USc—HR (112, 111); motor response (4.0, 4.5)

Trial 2

Control—HR (102, 111); motor response (2.4, 1.2)
(A) csa—HR (107); motor response (0.55)
USa—HR (112, 108); motor response (4.0, 6.5)

Control—HR (96, 92); motor response (3.5, 0.0)
(B) csb—HR (111); motor response (0.43)
USb—HR (107, 103); motor response (4.6, 6.3)

Control—HR (98, 91); motor response (0.0, 0.0)
(C) csc—HR (103); motor response (0.0)
USc—HR (114, 108); motor response (7.5, 8.8)

Trial 3

Control—HR (103, 102); motor response (3.3, 1.5)
(A) csa—HR (110); motor response (3.7)
USa—HR (103, 94); motor response (4.0, 6.8)

Control—HR (90, 89); motor response (2.5, 0.0)
(B) csb—HR (104); motor response (0.39)
USb—HR (105, 98); motor response (6.0, 7.8)

Control—HR (100, 101); motor response (3.5, 1.9)
(C) csc—HR (106); motor response (0.45)
USc—HR (123, 110); motor response (7.2, 15.8)

In these first three trials a cardiac change to the three auditory signals is more consistent than the motor change. Contrasting the motor responses occurring in the five-second period before the tone with those occurring in the tone period indicates that a motor response is about as likely to occur in a resting period as it is to the specific cs. The HR shows an increase starting with the auditory csb in Trial 2. The results for the four animals were consistent at this time.

These early responses indicate that the first change that occurs in an animal in this type of conditioning situation is an emotional sensitization or mobilization. The diffuse and generalized nature of the early cr is well established in conditioning literature (14). There was a general increase in motor restlessness in these early trials, which paralleled the changes in the resting HR.

The control HR averages before Trial 1 were somewhat above the average values for the last orienting session. These averages were based on four dogs, and all of them had a higher heart rate this day, especially the dog named Schnapps. It was an unseasonably warm day, and this may have accounted for part of the increase.

Table 2 gives cardiac and motor changes to the csi by three blocks of trials: the first two trials, the first 10 trials, and Trials 5-10. In this table, responses to the three csi are pooled. If the HR during a cs was higher than the HR before that signal, it was scored as a response. Any motor responses of the US leg occurring to the csi were scored as motor crs. There were no specific leg flexions in the early training.

This method of scoring should take into account the chance happening of a given response independent of the specific auditory stimulation. An HR change has a random occurrence of about 45 per cent. There are some ties; i.e., the control HR equals the HR to a stimulus. The motor response also has a chance frequency, which varied among the different animals. The frequency of motor stepping in the first 10 trials was tabulated for 30 periods of five seconds duration selected *randomly* midway between the successive tones, and the italicized figures, appearing after the name of each dog in Table 2, give the chance occurrence of a motor response.

When the various frequencies were compared by the chi-square technique (disregarding the correlation coefficients), it was found that the motor and the cardiac changes to tones were significant in three of the four animals. If attention is focused on the last five trials, HR is significant in every dog, and the motor response changes are significant in three dogs. It can not be concluded from these results that a cardiac response has any advantage in frequency over the motor cr in the first 10 trials.

Thus, the analysis of the first three trials shows a clearer predominance of cardiac activity to the auditory signals than motor activity, but by 10 trials the motor component is significant in most animals. One must be careful not to conclude that the autonomic activity reflects the emotional process, and that motor activity reflects the learning of a specific adaptation to the environment. All of the early responses seem to have an emotional significance, and it is only later that response specificity and differentiation emerge.

These motor and autonomic data were analyzed for *concomitance;* i.e., whether a cardiac excitation tends to appear on the same trial with a motor cr, and whether the cardiac change and the motor cr are both absent on the same trial. There is about a 45 per cent probability of obtaining a cardiac excitation accompanying any motor response. The concomitance in the last five trials was well above this theoretical expectancy for the dogs Isis and Blanket, but for the other two dogs the concomitance was considerably below the theoretical expectancy.

In these early trials, there was the beginning of a pattern which was to persist throughout conditioning, the tendency for the motor cr to be always accompanied by an acceleration in HR. It should be clear, however, that the HR change is not merely a sensory stimulation resulting from the motor movement, for it can occur in the absence of any motor movement and is often out of proportion to the magnitude of that

movement. Past work in this laboratory has indicated that the HR tends to accelerate to an inhibitory conditional stimulus where there is no motor cr (7, 8).

The HR of the four animals in the last training period for the orienting reflex averaged 91 and 90 beats/minute for control[5] and signal. By the end of the first conditioning session the control HR had increased to an average of 107, and the HR to the tones had increased to an average of 119.

B. *The development of differentiation.* Table 3, based on all dogs, contains an analysis of average HRs for various selected periods of time preceding, during, and following the three tones. The period 0-4 is the first four seconds of the cr period, and the period 4.6-5.5 is the UR period. R is a randomly selected 10-second period mid-way between the successive tones. The first block in Table 4 presents averages for the first 10 conditioning trials (Series 10); the second block relates to a test session of eight trials recorded between Trials 191 and 200 (Series 200); and the third block relates to the criterion test session of eight trials recorded for each animal's best performance, somewhere between Trials 360 and 467 (Series 400).

Table 4 summarizes the average motor results for these same conditioning series. The frequency of the motor cr is summarized in Column 1. The average latency for all motor cr's appears in Column 2. The latency for a single cr is considered as the period from the onset of the tone to the first recorded motor response.[6] Columns 3 and 4 give the average amplitude of the motor crs and URs. The amplitude for any response was taken as the maximum deflection of the kymograph pens both above and below the base line. Columns 5 and 6 give average activity duration (in seconds) for crs and URs. Column 5 is the combined activity for both the UR and the cr, and Column 6 is the UR alone. Column 7 is a summary of "anticipatory" behavior; i.e., the motor movements occurring within a 10-second period prior to the onset of the cs. The analysis here is comparable to that for motor frequency—the percentage of trials in which a leg movement occurred, and it is restricted to the US leg alone. With regard to the "anticipatory" movements, it is interesting that the averages tend to be higher than for the motor movements occurring in periods midway between the successive tones (Table 2), particularly in Series 200 and 400.

These data show that animals can be trained to give different HRs, motor response amplitudes, and motor response latencies to auditory signals representing different intensities of electrical stimulation. The average levels of response to the three tones for all animals were contrasted for each conditioning series by analysis of variance. The cr separation F values to the three tones were not significant in Series 10 for HR, motor latency, and magnitude. Corresponding significance tests for these three measures in Series 200 and 400 indicated that the crs to the three tones were significant with $p < .05$ in Series 200 and $p < .01$ in

[5] The term control is used to refer to the 5-second period preceding the presentation of the tones unless otherwise specified.

[6] If learning is acknowledged to be a central process, then in calculating latency it would be necessary to subtract the peripheral latency—that is to say, the latency between the central event and the peripheral manifestation. There is physiological evidence of quicker transmission to striated muscles than over autonomic paths to cardiac muscle. Since the transmission times appear to be but a fragment of the total response latencies, they are not considered.

TABLE 2

FREQUENCY OF THE CARDIAC AND THE MOTOR RESPONSES IN THE FIRST 10 CONDITIONING TRIALS

Animal	% Random Stepping	First 2 Trials—%			First 10 Trials—%			Trials 5–10—%		
		Cardiac crs	Motor crs	Concomitance	Cardiac crs	Motor crs	Concomitance	Cardiac crs	Motor crs	Concomitance
Isis	47	67	17	50	70*	73*	70	80*	100*	87
Blanket	30	50	50	66	73*	80*	73	93*	93*	87
Whittier	20	50	33	50	87*	43*	50	93*	47*	20
Schnapps	20	67	17	33	63	7	30	80*	0	20
Average	29	59	29	50	73	51	56	87	60	54

* $p < .05$ by χ^2.

Series 400. The between-animal *F* values were significant ($p < .05$) in all three conditioning series.

HR levels differed statistically to the three tones in Series 200 and 400 in terms of the one-second changes occurring during the tone period. Analysis of variance using the individual averages for each animal from second to second showed that HR levels to the three tones and changes from one second to the next during the tone interval were significant ($p < .01$). By Series 400 the pattern of HR changes to tones was well established. In Series 10 there was a tendency for a cardiac acceleration to occur during the first second of a tone. In later series there was a consistent tendency for an HR deceleration to occur during the first second of a tone followed by an acceleration to some maximum value.

Figures 1, 2, and 3 give the changes in differentiation from one recorded conditioning session to the next. Motor and HR differentiation follow a similar time scale.

The HR excitation to the tones showed an interesting phenomenon of gradually decreasing while differentiation increased. The motor crs were irregular: motor crb and motor crc increased during the first 200 trials and tended to decrease in the last 200 trials, and motor cra remained relatively constant throughout (neglecting the temporary changes in performance that were produced by the increases in USi). The fact that a motor cr even occurred to csa may be a reflection of increased sensitivity produced by the USi accompanying csb and csc. In any event, the averages for the motor cr to csa are based on fewer readings than for csb and csc, for the frequency was nearly always less (Table 4). Also, the reverse type of generalization must have been operating; i.e., the USa tending to influence the responses to csb and csc to decrease both their frequency and magnitude. The irregularities in the acquisition curves for the motor cr are very likely a function of the nature of this complex conditioning situation with its complicating emotional features.

Figure 1 shows that HR decreased from one conditioning session to the next except for those changes resulting from the alteration of the US. The rate of decrease is given by the three straight lines in this figure. The disturbance in behavior resulting from the change in the intensities of the USi after Series 200 was disregarded for purposes of this computation. The HR might have

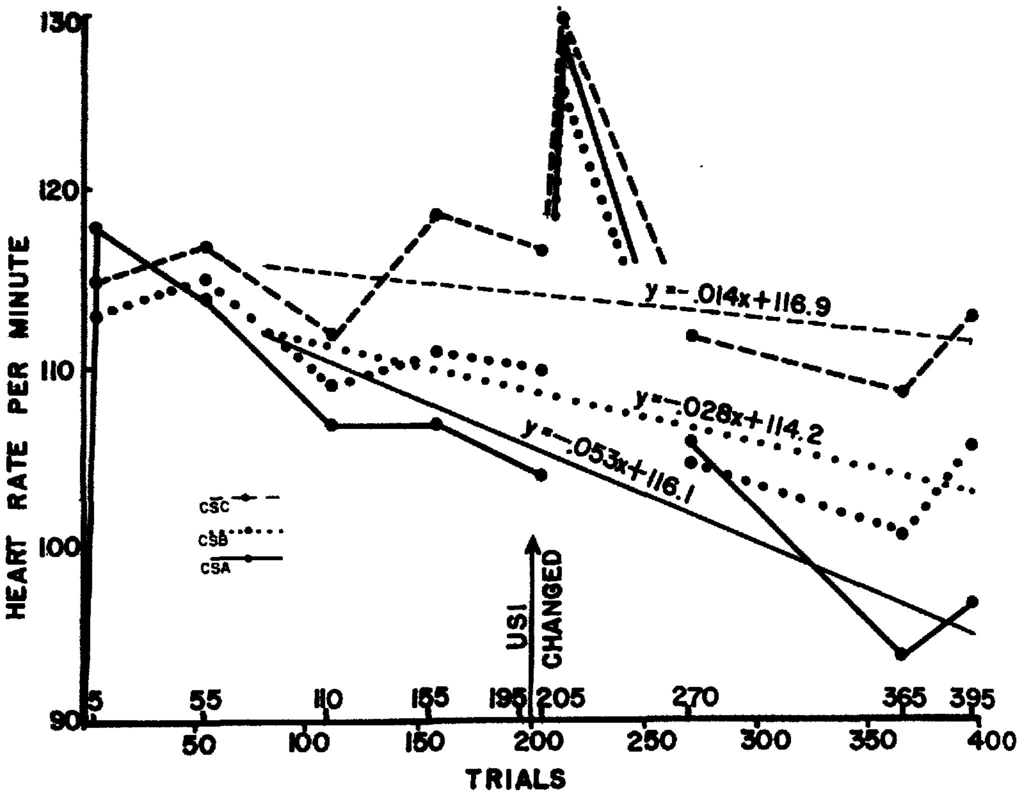
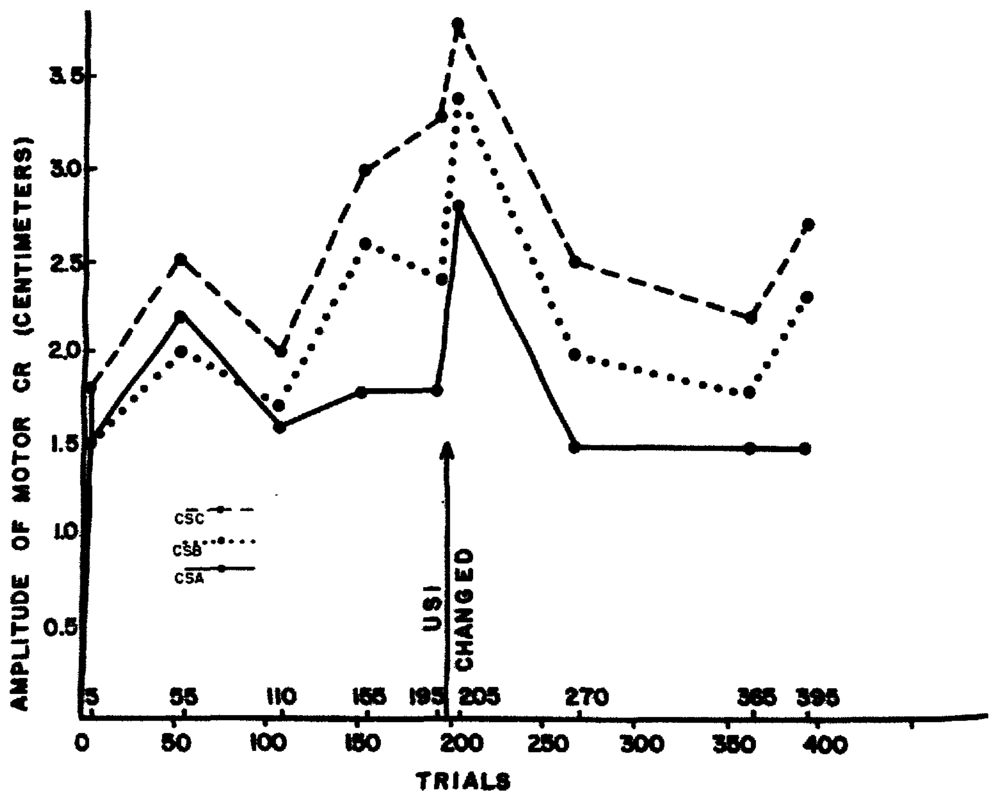


FIG. 1. Development of cardiac differentiation.



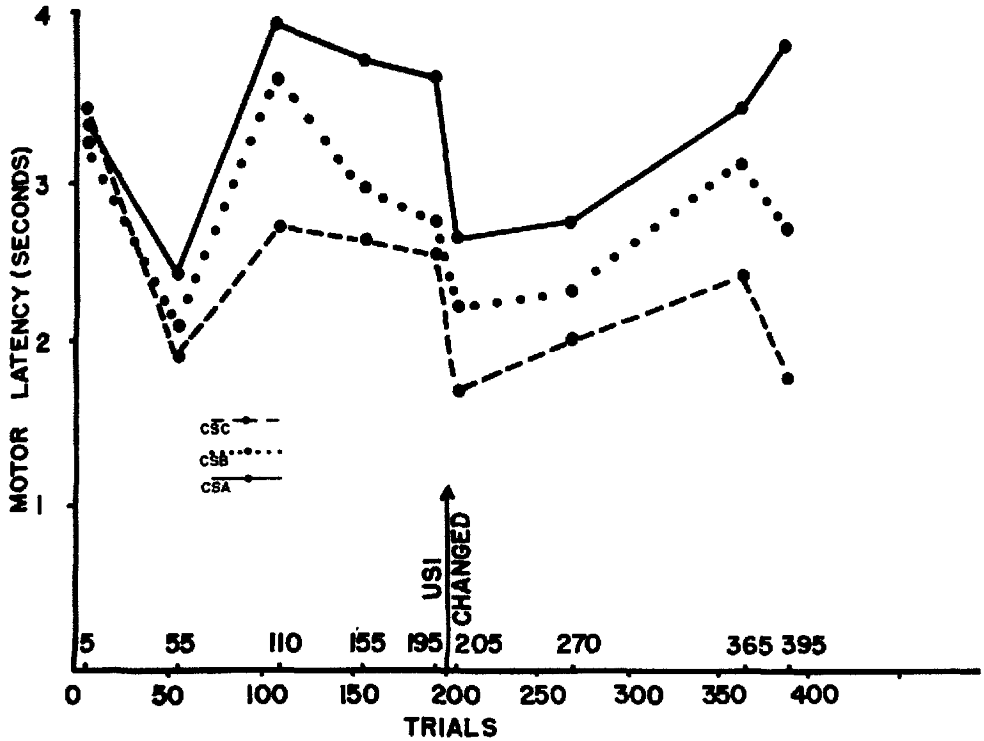


FIG. 3. Development of motor latency differentiation.

Note.—Figures 1, 2, and 3 show the development of differentiation and the effect of changing the USi intensities. Average responses to the three tones for various conditioning sessions covering the first 400 trials are given. The numbers appearing above the abscissa are the "middle" trial for each recorded conditioning session. All conditioning sessions plotted consisted of seven to ten repetitions of the three tones.

reached a lower level had it not been for these changes in the USi.

In general, all "irrelevant" motor movements (any movement other than that of the US leg) decreased with training. Any change in stimulation increased immediately the frequency and duration of random motor movements, such as the first time the tones were given, the first time the electrical stimuli were given, or when the intensity of reinforcement was changed following Series 200.

It may be of interest to note some of the changes in behavior that resulted from the changes in USi. All of the dogs except Isis stopped eating in the experimental room, and this lasted for over 100 conditioning trials. While the animals never appeared to be "fearful" about coming to the experimental room, they manifested symptoms of fear as soon as they entered it. Two of the dogs (Isis and Blanket), who would normally run in and jump up on the stand when called, would not do this following the USi changes. Blanket had to be led into the camera for all the remaining conditioning trials, whereas Isis, after 75 more conditioning trials, would run into the camera and jump up on the stand. Not only was differentiation impaired (Figs. 1, 2, and 3) but there was a considerable increase in the control HR and motor restlessness. *The effect of changing the*

TABLE 3

AVERAGE HR BEFORE, DURING, AND AFTER A CS-US SEQUENCE IN THREE SELECTED CONDITIONING SESSIONS (Time in Seconds)

CS	Pretone Period						Tone Period				UR	UR Period						R*
	25/15	15/10	10/5	5/0	2/1	1/0	0/1	1/2	2/3	3/4	4.6/5.6	6/7	7/8	5/10	10/15	15/20	20/30	
									Series 10 (10 trials)									
csa	102	106	105	108	105	107	110	117	121	128	122	117	108	113	112	109	106	104
csb	105	108	101	102	104	102	108	111	116	122	119	118	110	111	106	108	107	104
csc	108	107	108	112	113	114	114	111	116	119	126	131	116	119	115	110	108	106
									Series 200 (8 trials)									
csa	103	105	106	108	113	104	99	102	110	105	113	114	110	110	103	104	101	101
csb	104	100	102	101	102	104	104	114	114	113	117	123	118	117	109	103	101	104
csc	106	104	105	106	104	104	101	117	120	117	123	126	128	121	108	100	97	105
									Series 400 (8 trials)									
csa	102	100	100	102	104	101	92	95	101	101	104	101	99	101	102	99	98	98
csb	98	98	99	100	104	100	95	105	113	111	105	110	111	111	105	97	96	100
csc	100	100	103	106	110	111	105	114	126	125	117	116	123	119	107	97	97	101

* R is a randomly selected period mid-way between the tones.

USi impaired Blanket's differentiation for over 200 conditioning trials.

Suffice it to state here that the performance curves of Figs. 1, 2, and 3 indicate that behavior at any time is determined by a number of interrelated variables: (*a*) what the animal has learned in the situation, (*b*) novelty, (*c*) the "motivating" capacity of electrical stimulation, (*d*) adaptation, and (*e*) practice, or the number of conditioning trials. The individual constitution and past experience of the animal was a factor that showed up in the data of each dog. Although this is difficult to evaluate, there is no doubt about its significance.

Another question that comes up in regard to differentiation is the *consistency* of the differentiated response. For perfect HR differentiation on a given trial these conditions should be met:

1. HR to csa < csb,
2. HR to csb < csc,
3. HR to csc > csa.

Comparable conditions should hold for motor amplitude and (reverse) for latency. This analysis was carried out for several recorded test sessions; the data are shown in Fig. 4. This figure reflects the consistency of performance from one cs to the next in the various conditioning sessions. The important indication here was that *motor and HR differentiation developed approximately together,* although somewhat greater consistency is shown for motor amplitude than for motor latency and heart rate. The impairment in both motor and HR consistency following Series 200 resulted from the changes in USi intensities.

3. *The Development of a "Time Reflex" Resulting from the Use of Regular Stimulus Intervals*

The time reflex was not as consistent

TABLE 4

AVERAGE MOTOR RESULTS FOR THREE CONDITIONING SERIES

Series	cs	1 % crs	2 Latency (secs.)	3 cr Amplitude (cms.)	4 UR Amplitude (cms.)	5 Total Activity (secs.)	6 UR Activity (sec.)	7 % Anticipatory Activity
	csa	50	3.3	1.51	2.05	6.9	5.9	45
10	csb	55	3.2	1.53	2.26	6.6	5.5	30
	csc	48	3.4	1.83	2.66	8.2	6.9	38
	csa	68	3.6	1.80	2.40	3.9	2.9	50
200	csb	89	2.7	2.40	2.90	4.8	3.2	39
	csc	97	2.5	3.20	3.70	5.3	3.4	43
	csa	78	3.9	1.60	2.00	4.6	3.9	68
400	csb	100	2.6	2.30	3.60	6.6	4.8	45
	csc	100	1.8	2.70	4.40	8.8	6.0	63

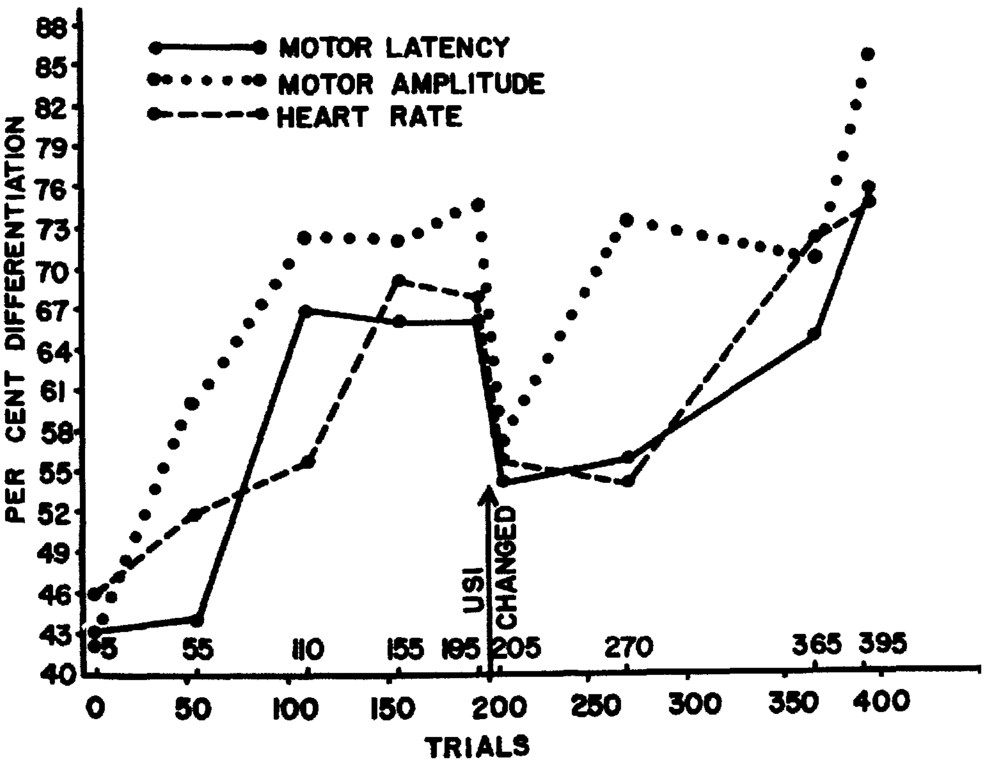


FIG. 4. Differentiation Comparison.

Note.—This figure contrasts HR, motor latency, and motor amplitude differentiation to the three auditory signals at various stages of the conditioning process. Conditioning sessions are the same ones that are shown in previous figures.

in this work as has been found in past studies of this laboratory (7,10). However spontaneous stepping gradually decreased during conditioning (except when stimuli conditions were changed), and all animals showed an increasing tendency to limit their stepping to periods just before the csi. These anticipatory motor flexions were accompanied in two dogs by whining, and one animal (Schnapps) went for several sessions stepping just a second or two before the onset of the conditioning tones. In general, the results were far more variable, and the time reflex took longer to develop than has been characteristic in past work. The complexity of this conditioning situation was probably detrimental to the establishment of such an anticipatory reflex.

4. *Instability of Behavior as Measured by the Standard Deviation*

The average HR standard deviations (beats/minute) were computed for tones and their 5-second control periods for the three orienting sessions and the three conditioning series. The orienting sessions included in Table 5 are the first and last, and one session just before the experiment with electrical stimulation. These orienting sessions are designated in Table 5 as 1, 3, and 2, respectively. This table does not show the changes in variability that followed the changes in the intensities of USi after Series 200. The variability was considerably increased by these changes.

The standard deviations for latencies of the motor crs were considerable in terms of the average values reported in Table 4. For Series 400 the standard deviation was 14 per cent of the average recorded value for csa, 19 per cent of the csb value, and 24 per cent of the csc value. When an animal is responding near the maximum level possible for a motor cr there tends to be a relatively greater variability in latency. Increased variability of the cr intensity under special stress has been previously noted by Pavlov (14) and Gantt (6).

The standard deviations relative to the mean amplitudes reported in Table 4 were high. In Series 400 variability was 45 per cent of the average for csa, 20 per cent of the average for csb, and 11 per cent of the average for csc. When an

TABLE 5

AVERAGE *SDs* FOR THE HEART RATE AND MOTOR CRS TO THE THREE TONES

Series		Tones	Heart Rate *SDs*				Motor Response *SDs* Conditioning	
			Orienting Reflex		Conditioning			
OR	C		Control	Tone	Control	cs	Latency secs.	Amplitude cms.
1	10	csa	11	12	15	14	.98	.50
		csb	12	13	15	15	1.10	.60
		csc	12	14	17	17	1.10	.55
2	200	csa	10	11	10	8	.98	.54
		csb	11	10	13	11	.76	.45
		csc	11	11	10	8	.54	.40
3	400	csa	10	11	14	11	.54	.72
		csb	11	10	16	11	.49	.45
		csc	9	11	15	14	.44	.31

animal is responding to the greater intensities of electrical stimulation, there is less relative variability in amplitude. The average standard deviations for the URs were analyzed for Series 200 and 400, and these results paralleled the amplitude of the cr in direction of change and relative variability.

The standard deviations relative to the mean HRs were also appreciable. The average HR to the tones in the last orienting session was 90, and a standard deviation of 11 is about 12 per cent of this average rate. In conditioning Series 400, a standard deviation of 11 to csb was 10 per cent of the average HR of 106, and a standard deviation of 14 was 12 per cent of the average HR of 117.

5. *Response Consistency*

There were two considerations here: (*a*) the fraction of total HR responses that show acceleration over control rates, and (*b*) the ratio of the total time the leg is flexed or in the process of flexing to the total time the leg is moving. This latter consideration involves two questions: the nature of the early motor responses to auditory signals and the change in these with conditioning. The orienting sessions were the same ones that were used in Table 5. It may be noted from Table 6: (*a*) that the cardiac component of the orienting reflex becomes somewhat more definite following the first session, and this persists for some time, returning to a chance level of consistency as the orienting reflex is extinguished; (*b*) that there is a marked increase in HR consistency in the first 10 conditioning trials, with no appreciable changes with subsequent training for csb and csc, but with a decrease for csa; and (*c*) that there is a gradual improvement in flexion specificity, which might be thought of as the "normal" physiological response to pain.

TABLE 6

CONSISTENCY PERCENTAGES FOR THE HEART RATE AND MOTOR CRS TO THE THREE TONES

OR	Series	csi	HR: Orienting: Per Cent Acceleration	HR: Conditioning: Per Cent Acceleration	Motor Response Conditioning: Per Cent Flexion
1	10	csa	45	75	70
		csb	58	75	65
		csc	48	70	60
2	200	csa	65	46	76
		csb	65	71	85
		csc	80	82	94
3	400	csa	45	41	84
		csb	48	69	92
		csc	45	74	100

6. *Comparison of HR and Motor Latency*

An important question is whether the HR response tends to appear before the motor response. The second-by-second HRs for all animals to the various tones in Series 200 and 400 were studied to determine the second in which HR exceeded the basal level, using the one-second average before the tones as the basal level.

The HR to csa exceeded or tied the basal level two to three seconds following the onset of csa, and the csb and csc responses exceeded the basal level one to two seconds following their csi. The average results were similar for Series 200 and 400. Table 3, which contains average values for the four dogs, reflects this. There were numerous instances in the individual trials of a cardiac change occurring within one second following the onset of tones, particularly in Series 10.

TABLE 7
THE INTERRELATIONSHIPS OF RESPONSE VARIABLES
(Series 400)

Y	*X*	ϵ_{yx}	Significance
cr HR	cr Motor amplitude	.49	$p < .01$
cr HR	cr Motor latency	.57	$p < .01$
cr HR	USi	.62	$p < .01$
cr Motor latency	USi	.62	$p < .01$
cr Motor amplitude	USi	.72	$p < .01$

These data indicate that the average HR latency is less than the average motor latency in the well-established cr (see Table 4). The latency of the HR response is a less precise measure than the latency of motor response. A study of the individual trials showed appreciable inconsistency from animal to animal, and within the same animals as to the precise time a cardiac change would appear following the onset of a given tone.

7. *Interrelations of Conditioning Variables*

Correlation ratios (ε) based on the 96 trials given the four dogs in Series 400 were computed to determine the interrelations of conditioning variables. The ratios, which are given in Table 7, show that on a given repetition of a tone-shock combination, the predictability of the absolute magnitude of any component of the cr is low. There tends to be a negative relationship between the prestimulus levels of HR and the stimulus levels of HR, and this factor confounds the ratios that involve HR. It should be apparent that a small change in HR from a high control value may be similar in magnitude to a large change from a low control value.

DISCUSSION AND SUMMARY

1. *Summary of Major Results*

It has long been recognized that the conditioning of a specific reflex, such as the leg-withdrawal reaction, results in the conditioning of the whole organism. The data of this monograph support this principle: the differentiated motor cr is accompanied by a differentiated HR.

This research has shown that the principles that have been developed for salivary and motor conditioning are also applicable to HR. HR is proportional to the intensity of the US; it is generalized to various signals in the early training trials; its differentiation develops gradually as a function of the number of trials; and the use of regular stimulus intervals produces a cardiac time reflex. The relationship of the HR response to the intensity of painful USi had not been previously worked out, although one of the authors had found evidence in a pilot study to suggest that the relationship is proportional (5) and had studied with Peters the effect of graded degrees of muscular tension on HR (15). The parallelism of the cardiac and the motor cr in differentiation was not expected. Past work in this laboratory (8) and theoretical considerations by Mowrer (13) led us to expect that cardiac differentiation would precede motor differentiation.

There was one significant departure from past observed conditioning results: the increased intensities of the shocks did not produce a permanent increase in the magnitude of the conditional motor and cardiac reactions. Figure 1 shows that HR decreased from one condition-

ing session to the next while the intensities of the reinforcing shocks were relatively constant—both within the first 200 and within the last 200 conditioning trials. The shock intensities, USc in particular, were increased at the end of the first 200 trials, and this had the effect of impairing differentiation and of increasing the magnitude of both motor and cardiac responses. Other interesting behavior changes occurred: animals showed an increased avoidance of the experimental room; three of the four dogs stopped eating in the experimental room and this lasted for over 100 conditioning trials; and motor restlessness was increased. Blanket, who would normally run in and jump up on the conditioning stand, had to be led into the camera for all the remaining trials.

The HR eventually returned to a lower rate than that which existed before the changes in shock intensity, and the motor cr showed a similar but less striking decrement. And all the other behavior changes, except for Blanket's reticence about entering the camera, disappeared before the completion of training. The precipitous drop in HR was completely unexpected, since past conditioning results lead one to believe that an increase in the intensity of the US, once a cr is elaborated, results in a permanent increase in the magnitude of the cr. The decrease in HR was not a reflex response arising from an increased blood pressure. Other work on blood pressure in this laboratory, which we are now preparing for publication, indicates that blood pressure exhibits a similar intersession decrement.

2. *Autokinesis*

When maladaptive behavior develops in the absence of day-to-day stimulation other than that which confronts the animal in the kennels, it is termed autokinesis (6, 8). Autokinesis is said to be present whenever reactions previously restricted to one set of organ systems spreads to involve additional organ systems, or whenever reactions within each separate organ system are greatly intensified; e.g., a mild cardiac acceleration to a tone may become a tachycardia when the animal is introduced to the experimental environment, to the sight of the experimenter, or to stimuli only remotely connected with the original stress conditions (8).

In this research, an *opposite* self-regulative tendency was found. It would appear that autokinesis can be a two-way process—destructive or constructive—and that the direction of the reaction is determined by the nature of the stress conditions and the constitution of the animal. Although novelty may reverse the constructive autokinetic tendency, the novel conditions of this work did not produce an irreversible change.

In explaining the autokinetic tendency of self-regulation, we would postulate that the day-to-day shocks not only reinforced the specific responses to tones but acted in addition as a reinforcement of mildness. Two dogs used as subjects were retested about one month after the end of the experiments reported here. While their differentiation was only moderately impaired, their HR increased in both the stimulus and prestimulus periods. These animals appeared to be far more apprehensive in the experimental environment.

The type of emotional state that noxious stimuli initiate might be termed *apprehensive expectation,* as opposed to the state produced by rewarding stimuli, which might be termed *eager expecta-*

tion. It is suggested that the constructive autokinetic tendency observed here was permitted by a decrease in the level of apprehensive expectation.

3. *Autokinesis and Differentiation*

In this research, the differentiation and self-regulative autokinetic processes tended to be inversely related. This is not always the case. Bridger (1), using a faradic stimulus from an inductorium, found that the HR of his dogs increased on subsequent days, and yet the animals gave perfect differentiation. It is quite possible, however, that autokinetic reactions must fall within certain limits before differentiation can occur, and the study of these limits is an interesting problem for future research. It is suggested that a slow rate of self-regulative autokinesis, or its absence independent of destructive autokinesis, serves as a warning of psychopathology.

4. *Schizokinesis*

Whitehorn (18) and Mowrer (13) have proposed that learning consists first of emotional arousal, and that such arousal, if not too intense, motivates motor, cognitive, or problem-solving behavior. Mowrer describes the emotional arousal system exclusively in terms of autonomic conditioning. Whitehorn has described the emotional arousal thus:

> . . . a biological condition, characterized subjectively as an excited, tense feeling with considerable tendency to act, but with uncertainty as to what to do, and characterized objectively by motor restlessness or activity, not smoothly patterned, with indications of excess effort, as shown in the facial and respiratory musculature, tremor of the voice, and skeleto-muscular action, together with sudden changes in visceral activity. . . . This experience is found, in general, to be unpleasant (18, p. 260).

It has been observed in the past work of this laboratory that the cardiac response often appears before the motor response in conditioning, and that it outlasts the motor response in retention or extinction. Such a split between autonomic and motor responses has been called schizokinesis (6, 8, 9). The evidence for schizokinesis tends to support Mowrer, who has stated, in effect, that a lack of integration (schizokinesis) is the fundamental basis of learning.

The data of the present study offer two ways of evaluating Mowrer's theory: response acquisition and differentiation. Differentiation, as stated before, was characterized by response integration: there was a striking parallelism of HR and motor crs. With regard to response acquisition, the cardiac response had no advantage in frequency of occurrence over the motor cr in the first 10 repetitions of the three tones and their three shocks, but the cardiac response gave some evidence of earlier conditioning when the analysis was restricted to the first three trials. The significance of this latter is highly suspect: all the early motor crs had the appearance of emotional responses; and more important, the HR was electrically recorded, while the motor crs were mechanically recorded. It is thus possible that the early motor responses were missed by our method of recording.

Whether an autonomic response is a better indicator of emotionality than a motor response depends on the subject. Malmo and Shagass (12) have demonstrated that muscle potentials are as good a reflection of emotionality as changes in HR. Also, cardiac acceleration per se is not necessarily an indication of emotional behavior, for while high HRs are obtained by the injection of moderate doses of acetylcholine, animals give no evidence of being emotionally disturbed

and these changes in HR cannot be conditioned (17).

In summary, it is believed that the results of the present conditioning study support a dual factor learning theory. Whereas Mowrer identifies autonomic conditioning with the emotional factor, excluding motor responses, we believe that normal, healthy learning is characterized by an *integration* of autonomic and motor responses, at both the emotional and the problem-solving levels. It is suggested that any lack of integration (schizokinesis) occurring at any point in the conditioning process is indicative of psychopathology.

REFERENCES

1. BRIDGER, W. Effect of mescaline on higher nervous activity. *Amer. J. Psychiat.*, in press.
2. DYKMAN, R. A., & GANTT, W. H. A comparative study of cardiac and motor conditional responses. *Amer. J. Physiol.*, 1951, 167, 3. (Abstract)
3. DYKMAN, R. A., & GANTT, W. H. A comparative study of cardiac conditioned responses and motor conditioned responses in controlled "stress" situations. *Amer. Psychologist*, 1951, **6**, 263. (Abstract)
4. GANTT, W. H. The nervous secretion of saliva: quantitative studies in the natural unconditioned reflex secretion of parotid saliva. *Amer. J. Physiol.*, 1937, 119, 493-507.
5. GANTT, W. H. Cardiac conditional reflexes to painful stimuli. *Fed. Proc.*, 1942, 1, 28. (Abstract)
6. GANTT, W. H. *Experimental basis for neurotic behavior*. New York: Hoeber, 1944.
7. GANTT, W. H. Cardiac conditional reflexes to time. *Trans. Amer. Neurol. Ass.*, 1946, 71, 166. (Abstract)
8. GANTT, W. H. Principles of nervous breakdown-schizokinesis and autokinesis. *Ann. N.Y. Acad. Sciences*, 1953, **56**, 143-163.
9. GANTT, W. H., & DYKMAN, R. A. Experimental psychogenic tachycardia. *Amer. J. Physiol.*, 1952, 171, 725. (Abstract)
10. GANTT, W. H., HOFFMAN, W. C., & DWORKIN, S. The cardiac conditional reflex. *17th Int. Physiol. Congr.*, 1947, 15-16. (Abstract)
11. LIDDELL, H. S. Adaptation on the threshold of intelligence. In J. Romano (Ed.), *Adaptation*. Ithaca: Cornell Univer. Press, 1949.
12. MALMO, R. B., & SHAGASS, C. Physiologic studies of reaction to stress in anxiety and early schizophrenia. *Psychosom. Med.*, 1949, 11, 9-24.
13. MOWRER, O. H. *Learning theory and personality dynamics*. New York: Ronald, 1950.
14. PAVLOV, I. P. *Lectures on conditioned reflexes*. (Trans. by W. H. Gantt.) New York: International Publishers, 1928.
15. PETERS, J. E., & GANTT, W. H. Conditioning of human heart rate to graded degrees of muscular tension. *Fed. Proc.*, 1951, 10, 104. (Abstract)
16. ROBINSON, J., & GANTT, W. H. The orienting reflex (questioning reaction): cardiac, respiratory, salivary and motor components. *Bull. Johns Hopkins Hosp.*, 1947, 80, 231-253.
17. TEITELBAUM, H. A., & GANTT, W. H. A method of intravenous injection of drugs from a distance in conditional reflex studies. *Science*, 1951, 113, 603-605.
18. WHITEHORN, J. C. Physiological changes in emotional states. *Res. Publ. Ass. nerv. ment. Dis.*, 1939, 19, 256-270.

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